3:30pm - 4:00pm (Invited)
SSL5.1 Room B1

Tunable, single-frequency, erbium fiber ring lasers

Kerry J. Vahala, Namkyoo Park, Jay Dawson and Steve Sanders
Department of Applied Physics
California Institute of Technology, Pasadena, California 91125

Abstract: Tuning range, side-mode suppression, line width, and intensity noise are reviewed for an all-fiber erbium ring laser. Active stabilization to an external fiber Fabry-Perot resonator is demonstrated.

Lasers employing rare-earth doped fiber amplifiers have received a considerable amount of attention in recent years. We consider a subset of this growing class of devices: single frequency, all-fiber lasers based on erbium fiber amplifiers. During the last two years, considerable progress has been made in this specific device class. Three research groups, including our own, have reported devices that exhibit stable single frequency operation [1,2,3]. The geometry that we have demonstrated is a unidirectional ring oscillator in which isolated, tandem fiber Fabry-Perot (FFP) filters provide both tuning and mode selection. A schematic of this device showing the essential elements is presented in figure 1. The erbium doped fiber amplifier module (EDFA), output coupler with power coupling ratio K, isolators, and both broad-band (BB) and narrow-band (NB) FFP filters are indicated. The broad-band fiber Fabry-Perot filter has a free spectral range (FSR) of 4020 GHz and a full width at half maximum (FWHM) transmission of 38 GHz. This is sufficient to provide coarse tuning of the ring laser, but insufficient to stabilize a single longitudinal mode of the ring (the ring FSR is 4 MHz). The narrow-band FFP with a FSR of 10.2 GHz and FWHM of 130 MHz provides sufficient mode selection to fully stabilize the ring. Single longitudinal lasing with side mode suppression exceeding 60 dB over the entire tuning range has been demonstrated.

Recently, we have reported the first measurements of intensity noise in fiber lasers [4,5]. Using a balanced homodyne detection system, we initially measured an intensity noise floor approximately 20 dB above the standard quantum limit (SQL) for the single frequency ring in figure 1. In a later study, however, we were able to reduce this noise floor all the way to the SQL by reconfiguring the ring and optimizing the output coupling ratio [5].

Measurements of the single-frequency line width of this device will also be reviewed. To make these measurements we have demonstrated a new version of the delayed self heterodyne measurement in which an active recirculator is used to greatly extend the resolution of the device. The recirculator allows measurement of heterodyne line width for various amounts of temporal delay. This allows the exploration of both short term and long term contributions to line width [6]. Figure 2 shows measured line width for various amounts of temporal delay. The instrument resolution is also shown in the same plot. Long term (msec time scale) contributions to line width in this device are attributed to microphonic disturbances and put an upper bound of approximately 4 kHz on the device tested [7].

Further improvements to this device now under way as well as applications of the device will be discussed. In particular, an actively stabilized ring laser has been demonstrated [8]. This system uses the Pound-Drever technique to lock the lasing frequency to a resonance of an external fiber Fabry-Perot etalon [9]. A schematic of the system is illustrated in figure 3. Experiments currently underway to lock multiple ring lasers to a single fiber Fabry-Perot will also be discussed.

References

[1] N. K. Park, J. W. Dawson, K. J. Vahala, C. Miller, *Appl. Phys. Lett.* **59**, 2369 (1991).
[2] J. L. Zyskind, J. W. Sulhof, Y. Sun, J. Stone, L. W. Stulz, G. T. Harvey, D. J. DiGiovanni, H. M. Presby, A. Piccirilli, U. Koren, R. M. Jopson, *Electron. Lett.*, **27**, 2148 (1991).
[3] G. A. Ball, W. W. Morey, Proceedings of OFC 1992, paper # WA3.
[4] N. K. Park, S. Sanders, J. W. Dawson, K. J. Vahala, Proceedings of CLEO 1992, paper CWE5.
[5] S. Sanders, N. K. Park, J. W. Dawson, K. J. Vahala, *Appl. Phys. Lett.*, **61**, 1889 (1992).
[6] J. W. Dawson, N. K. Park, K. J. Vahala, *IEEE Phot. Tech. Lett.*, **4**, 1063 (1992).
[7] N. K. Park, J. W. Dawson, K. J. Vahala, *Optics Letters*, **17**, 1274 (1992).
[8] N. K. Park, J. W. Dawson, K. J. Vahala, *Optics Letters*, **18**, 879 (1993).
[9] R. W. P. Drever, J. L. Hall, F. V. Kowalski, J. Hough, G. M. Ford, A. J. Munley, H. Ward, Appl. Phys. **B31** 97 (1983).

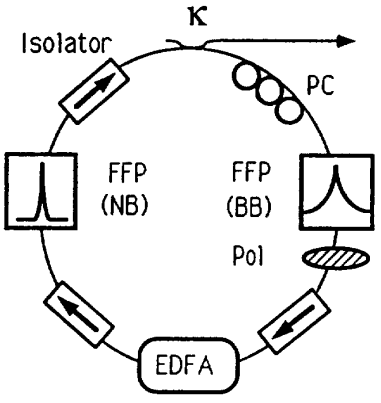

Figure1: Schematic of single frequency tunable erbium fiber ring laser.

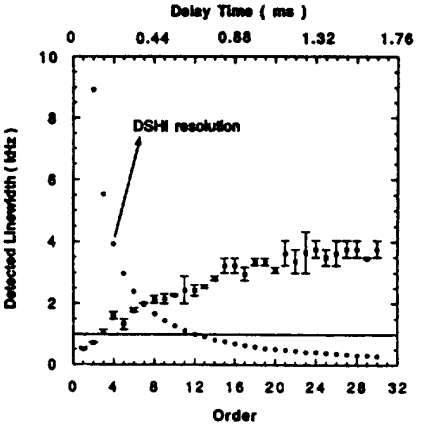

Figure 2: Laser line width versus delay time in recirculator. Dashed curve is instrumental resolution.

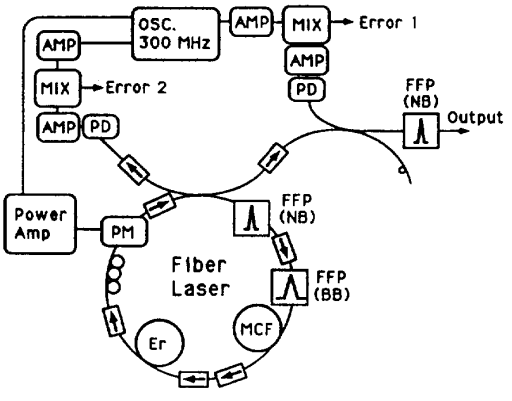

Figure 3: Fiber ring laser incorporating an all-fiber Pound Drever stabilization system.